

Chapter 6 – Environmental performance of constructions

Coordinator: Valeriu Stoian

6.1. Towards energy-efficient buildings in Europe

Heli Koukkari

VTT Technical Research Centre of Finland, Espoo, Finland
heli.koukkari@vtt.fi

Luís Bragança

University of Minho, School of Engineering, Department of Civil Engineering, Guimarães, Portugal
braganca@civil.uminho.pt

6.1.1 INTRODUCTION

The New Energy Policy was adopted by the European Council in spring 2007 (EC2008). Later in December, 2008 the European Parliament adopted a number of measures designed to: establish a new energy policy, combat climate change, and boost the EU's energy security and competitiveness. This integrated climate change and energy policy (EU 2002) aims to ensure that Europe has a sustainable future based on a low-carbon, energy-efficient economy. The ambitious targets of the agreement were identical with the Action Plan on the energy-efficiency of European Commission that introduced the goal to limit raise of the global average temperature to 2°C, compared to pre-industrial level (EU2007a). To achieve this, the EU is promoting a goal of 30% reduction in greenhouse gas emissions by 2020, compared to 1990 levels, in developed countries. Further, it has made an independent commitment to achieve at least 20% reduction. The targets for various measures up to 2020 in the EU include:

- 20% improvement of energy-efficiency of cars, buildings and appliances, and especially
- 30% reduction of final energy use of buildings
- 20% share of renewable energy in average
- 10% share of biofuels
- ≈0% emissions of new power plants.

The carbon dioxide (CO₂) is dominant among the greenhouse gases (GHG). A major part of CO₂ emissions is related to energy, either to production or consumption, and combustion of coal and oil fuels is the main emitter. The Kyoto protocol states a goal to reduce the amount of six Greenhouse gases at least by 5% by the year 2012 compared with the year 1990; the EU-15 countries have agreed a target of 8%.

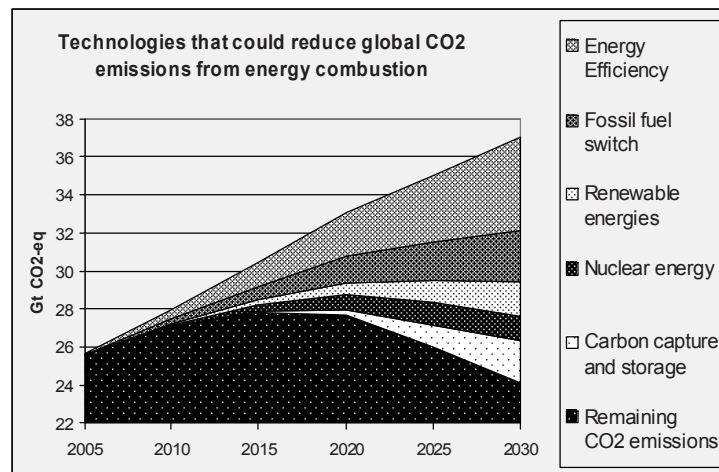


Figure 6.1.1. Potential of various technologies to affect globally to GHG emissions.

According to the communication of Commission of the European Communities (2007), most technologies to reduce GHG emissions either exist or are at an advanced stage of preparation and can reduce emissions (see Figure 6.1.1). This view concerning the construction sector has been stated by the Intergovernmental Panel on Climate Change, too (IPCC 2007).

For the EU, reducing overall consumption of energy is of great importance due to commercial and political reasons, too. The European Environment Agency calls the situation as “twin-challenges of climate change and energy supply security” (EEA 2006a). Dependence on the imported primary energy is expected to grow up to 70% in 2030 when it is nowadays 54% (Commission of the European Communities 2001, EEA 2008). In the EU, use of the residential and tertiary sector buildings consumes roughly 40% of total final energy use. Their energy needs are satisfied mainly by oil and gas - around 60% - whose import dependence e.g. on Russian sources is great.

From the points of views of sustainable construction, the “twin-challenges” are only a part of the picture: the fossil fuel depletion is a serious environmental load. In the Life-Cycle-Analysis of a building, the energy used in the construction process comprises the direct energy used on the construction site and the indirect energy used in the manufacture of the building materials. The indirect energy component, known as embodied energy of materials, is increasingly being considered because manufacture of construction materials uses about 1/3 of all energy used in industries. Also, the relative importance of the embodied energy is rising when energy consumption for operation of buildings is reducing.

For all these reasons, improvements in the energy-efficiency of the European construction sector, and especially that of the existing building stock, are important for the sustainability of the construction sector. Among the measures to response the challenges, the EU is expanding the scope of the Directive on Energy performance of buildings and introducing EU performance requirements that promote concepts of very low energy and neutral energy buildings.

The purpose of the paper is to give an overview on the energy consumption and energy-related emissions of the European building stock, and technologies available to respond to the challenge of major savings. Further, the state-of-the-art of methods to verify the energy performance of buildings as a part of a sustainability assessment is studied. The methods of the study are surveys on statistics and literature.

6.1.2 ENERGY, EMISSIONS AND BUILDINGS IN PRACTICE

6.1.2.1 *Statistics about energy and buildings*

The European buildings are argued to be responsible of around 40% of the total final energy consumption. However, this proposition of consumption consists of two parts: operation of technical systems (heating, cooling, ventilation, warm water) and use for work and living (lighting, appliances, elevators, computers, home entertainment, saunas). The importance of this separation is due to the role of users; in particular the latter part is highly dependent on user's behavior and aspirations.

The overall energy consumption is as such an important factor of greenhouse gas emissions: energy-related greenhouse gas (GHG) emissions account for 80 % of the total emissions (EEA 2008). Decreasing energy demand of operation and use of buildings is thus beneficial in any circumstances. On the other hand, production and sources of energy are extremely important for the impacts that are commonly and shortly addressed to “buildings”. The largest emitting economic sector in Europe is electricity and heat production, and transport follows. Both of these sectors affect in turn the energy use of the “built environment”.

Several approaches have been developed in recent years in order to support the demanding political decision-making. The European Environment Agency EEA has introduced a set of energy and environment indicators that are a part of the EU's indicators for sustainable development (EEA 2006b, Eurostat 2009). These indicators include e.g. final energy consumption by sector, greenhouse gas intensity (including carbon intensity), and total energy consumption by fuel/energy source.

The energy consumption in and of buildings is one category in statistics that in common apply three main categories (“sectors”) of Industry, Buildings and Transport. The category of

buildings excludes industrial buildings, and consists of two subdivisions: residential and tertiary, or households and service sector. The tertiary or service sector includes offices, wholesale and retail trade, hotels, restaurants, schools, hospitals, sport halls, indoor swimming pools etc.

In Table 6.1.1, the final energy consumption in the EU is presented. (One should take a notice that there are slight differences between various EU documents, and starting from the Eurostat or national statistics is recommended; further, the statistics tend to become more precise over time.) In figures, the negative sign of dependence shows net export of energy, and the Figure 6.1.above 100% is caused by situation of stocks. The proportions of households and services of the final energy consumption is calculated here based on the total energy consumption by country shown in the reference statistics.

Table 6.1.1. The import dependency of gross inland consumption; total and per capita CO₂ emissions; final energy consumption of households and services; and proportion of space heating inside these two sectors. (The temperature correction is not taken into account)

Country	CO2 emissions in 2006 (EC 2009)		Import dependency (EEA 2008)	Final Energy Consumption in households and ser- vices in 2006, and its proportion of total con- sumption of all sectors (Mtoe = Million tons of oil equivalent; and 1 Mtoe = 11630 GWh or 41868 TJ according to IEA)				Space heating alone of energy consumed in- side the respective sector 2004 (EC 2007)	
	Total	Per cap- ita	2006	Households & Services		House- holds alone	Proportion of house- holds	House- holds	Services
				Totally	Proportion				
	Mt	tn	%	Mtoe	%	Mtoe	%	%	%
BE	150	14.2	77.9	14.1	36.9	8.9	23.3	77	69
BG	55.9	7.3	46.2	3.4	34	2.2	22	-	-
CZ	129	12.6	28	10.5	40.1	6.5	24.8	77	75
DK	63.6	11.7	-36.8	7.4	47.4	4.4	28.2	67	45
DE	910	11	61.3	104.1	46.7	69.1	31	77	47
EE	16.7	12.4	33.5	1.4	50	0.9	32.1	72	41
EL	122.3	12	90.9	8.7	40.5	5.5	25.6	76	63
ES	395.9	9	71.9	27.2	27.9	14.8	15.2	55	20
FR	429.8	6.8	81.4	72.1	45.7	44.6	28.3	75	55
IE	50.6	11.9	51.2	4.9	37.7	3.1	23.8	68	61
IT	503.8	8.5	86.8	48.4	37	29.9	22.9	68	62
CY	9.7	12.5	102.5	0.6	33.3	0.3	16.7	0	0
LV	9.1	4	65.7	2.3	54.8	1.5	35.7	78	91
LT	15.1	4.4	64	2.2	46.8	1.4	29.8	75	58
LU	13.3	28.2	98.9	0.7	15.9	0.6	13.6	73	47
HU	61	6.1	62.5	9.8	54.7	6.2	34.6	71	68
MT	5.3	13	?	0.1	20	0.1	20	0	0
NL	239	14.7	38	21.8	42.9	10	19.7	68	81
AT	79.1	9.6	72.9	10.3	38.4	6.6	24.6	74	62
PL	332.7	8.7	19.9	30	49.3	19.2	31.6	75	75
PT	68.4	6.5	83.1	5.7	30.8	3.2	17.3	18	36
RO	111.5	5.2	29.1	10.9	44.1	7.8	31.6	-	-
SI	17	8.5	52.1	1.7	34.7	1.2	24.5	72	62
SK	40.1	7.4	64	4.3	40.2	2.3	21.5	0	61
FI	71.3	13.5	54.6	8.4	31.5	4.9	18.4	59	64
SE	60.7	6.7	37.8	11.9	35.8	7	21.1	51	47
UK	597.2	9.9	21.3	60.9	40.5	42.1	28	60	57
All	4560	11	53.8	483.9	41.1	304.3	25.9		

In average, the operation and use of buildings account roughly for about 40% of total final energy consumption; this Figure 6.1.includes all energy consumption. The division between households and services is roughly 60 and 40%. Inside these statistical sectors, control of the indoor temperature consumes the major part of energy (traditionally heating dominates). Table 6.1.1 shows thus some directions for planning of technical improvements of the European building stock but true impact analysis needs also data about energy mix.

Six countries with the greatest numbers of population account for 820 Millions tons of equivalent oil (Mtoe's) as the final energy consumption out of 1177 which makes 70%. These countries are Germany, France, Italy, Poland, Spain and the U.K. The same countries account for 3070 Mt's of CO₂ emissions that are about two thirds of the total amount of 4560 Mt's.

When the efficiency of various energy saving measures is studied, differences between macro-economic indicators of countries cannot be overlooked, like energy sources used for

space heating, green house gas intensities and import dependency. The “energy profiles” produced and published by Eurostat give detailed information by fuel how the final energy is supplied to the various sectors (Eurostat 2009). However, further data would be still be needed how e.g. use of electricity is divided to operation and use of building. The average European values are more indicative, and give information about trends at the EU level (Table 6.1.2). The new data shows that a reduction in energy consumption took place in EU27 in 2007 on which the German taxation policy had a great influence (EEA 2009^b).

Table 6.1.2. Proportion of households and services sector in final energy consumption by fuel in EU27 in 2006 (Eurostat 2008). About conversion coefficients see Table 6.1.1.

Final energy demand by fuel	Total final energy demand	Residential buildings alone	Buildings (residential and tertiary)	Share of energy sources used for buildings	Proportion of buildings by fuel	Proportion of buildings of the total final energy demand, %
	Mtoe	Mtoe	Mtoe	%	%	%
Solid fuels	55	9.9	12.5	2.6	22.7	1.1
Petroleum products	496	53.2	74.1	15.4	14.9	6.3
Natural gas	268	120.3	174	36.1	64.9	14.8
Electricity	243	69	137.4	28.5	56.5	11.7
Derived heat		20.1	29.8	6.2		
Renewables	59	32.9	36.5	7.6	61.9	3.1
Else			17.3	3.6		
Total	1175		481.6	100		

6.1.2.2 Energy indicators of the European building stock

The energy indicators of buildings are related on the other hand to the typologies of the building stock and on the other hand to social and demographic information. For example, increasing wealth, decreasing size of households and increasing usable area per person indicate that the overall consumption of households would still increase. The slow replacement of old building stock - only 0.07% in average - is a factor that supports this trend.

In analysis of various retrofitting needs of buildings, it is common to classify the building stock into age groups according to the completing years. This approach is justified due to the similar building technologies. Table 6.1.3 gives basic information for energy-related indicators of the building stock. However, the official national statistics should be used in studies because there are differences between sources; the UNECE and Boverket have some great differences.

The number of dwellings in EU-27 is about 215 millions, of which about three fourths is concentrated in six countries: Germany (18.0%), Italy (12.3%), UK (11.9%), France (13.7%), Spain (9.7%), Poland (5.5%).

There is a significant difference between occupied (treated) floor area and the total area. Again, one should have a real data about the heated area when indicators like consumption per m^2 or m^3 or the potential of energy savings are evaluated. For example, in Finland there is a stock of secondary houses that is more and more used also during the winter time, and thus heated to some extent.

Several European studies have been performed concerning indicators and data needed for the evaluation of the energy performance of buildings. As the most accessible data concerns residential buildings, the work has very much concerned to it. The list of Odyssee project is similar with the indicators used in practical assessments (Odyssee 2007):

- Unit consumption per households (total, for various purposes, per m^2 , with climatic corrections, in useful energy)
- Energy efficiency index
- Specific consumption of new dwellings (per m^3 , flat, houses)
- CO₂ emissions (direct, total, per dwelling, for space heating)

Table 6.1.3. Characteristics of European building stock related to energy (UNECE 2007, Boverket 2005)

Country	Population 2008 (EU 2009) x10 ³	Dwellings in total		Age distribution of the housing stock (Boverket 2005)					
		Number Millions	Total area per person, m ²	< 1919	1919 - 1945	1946 - 1970	1971 - 1980	1981 - 1990	> 1990
BE	10 667	4.8	86.3	15.0	16.5	29.0	15.2	9.2	15.1
BU	7 640	3.7							
CZ	10 381	4.3	76.3	10.9	14.7	26.3	22.5	16.4	8.2
DK	5 476	2.6	109.1	20.2	16.9	28.3	17.6	9.7	7.4
DE	82 218	38.9	89.7	14.6	12.6	47.2	10.9	14.6	-
EE	1 341	0.6	60.2	9.4	14.2	30.0	21.5	19.6	5.3
EL	11 076	5.5	82.7	3.1	7.2	31.8	24.5	19.1	14.3
ES	45 283	20.9	90.0	8.9	4.2	33.5	24.1	13.6	15.7
FR	61 876	29.5	89.6	19.9	13.3	18.0	26.0	10.4	12.4
IE	4 401	1.4	104.0	9.7	8.2	16.4	17.5	16.2	31.9
IT	59 619	26.5	90.3	18.0	19.0	47.3	18.2	9.4	7.1
CY	789	0.3		-	7.4	16.9	20.7	27.4	27.1
LV	2 271	1.0	55.4	11.0	13.8	27.7	22.6	21.1	3.7
LT	3 366	1.3	60.6	6.2	23.3	33.1	17.6	13.5	6.3
LU	484	0.2	125.0	11.9	14.8	27.0	14.9	11.6	17.1
HU	10 045	4.1	75.0	13.9	12.5	26.1	22.3	17.7	7.4
MT	410	0.1	106.4	14.9	11.0	29.4	16.9	15.8	11.8
NL	16 405	6.8	98.0	7.1	13.2	30.9	18.9	29.8	-
AT	8 332	3.3	92.9	18.6	8.1	27.4	15.9	12.4	17.6
PL	38 116	11.8	68.2	10.1	13.1	26.9	18.3	18.7	12.9
PT	10 618	5.3	83.0	5.9	8.5	22.9	18.3	44.4	-
RO	21 529	8.1							
SI	2 026	0.8	75.0	15.3	7.9	28.1	23.6	16.2	8.7
SK	5 401	1.7	56.1	3.4	6.6	35.1	25.6	21.0	6.8
FI	5 300	2.6	77.0	1.6	8.8	30.6	23.4	20.0	14.4
SE	9 183	4.4	91.6	12.4	20.2	33.1	17.4	9.7	7.2
UK	61 186	25.6	86.9	20.8	17.7	21.2	21.8	18.5	-

Data and information needed in evaluation of energy used in the building stock can be found more frequently in publications, based on several European and international projects and networks, like e.g. International Energy Agency IEA (2007), European Programme for Intelligence Energy Europe IEE in the Competitiveness and Innovation Framework Programme (IEE 2007), European Framework Programmes for Research (especially Themes for Environment and Energy) and COST Actions.

6.1.2.3 Potential of energy-efficiency of buildings

Energy saving in the European building stock is a paramount effort of the construction sector at the moment. Three types of objectives exist: reduction of total final energy consumption up to the amount that is consumed for operation, reduction of energy-related greenhouse gas emissions and savings up to 80% of the operational costs. Energy-efficiency is a central part of the European Economic Recovery Plan (Commission 2008) that channels funding to R&D activities, too.

Estimated amounts of the greenhouse gas emissions from buildings and their use vary in large ranges in presentations and publications. The highest estimation says “Energy use in buildings accounts for about 70% of the total CO₂ emissions associated with the use of energy in the City of Toronto (Harvey 1994). In EU27, residential and service sector buildings account less than 20% of GHGs when the production of electricity and district heating is not taken into account (EEA 2008). However, one EraBuild report tells about “the importance of reducing energy consumption in buildings - responsible for over 40% of Europe's greenhouse gas emissions” (Itard et al 2008). Many publications tell about USA that buildings account close to half of CO₂ emissions. The differences in data are in common caused by the method how electricity consumption is taken into account but there are also differences in ways the statistical data is collected and recorded. Figure 6.1.2 presents the context in which the energy consumption and energy-related GHG emissions are considered.

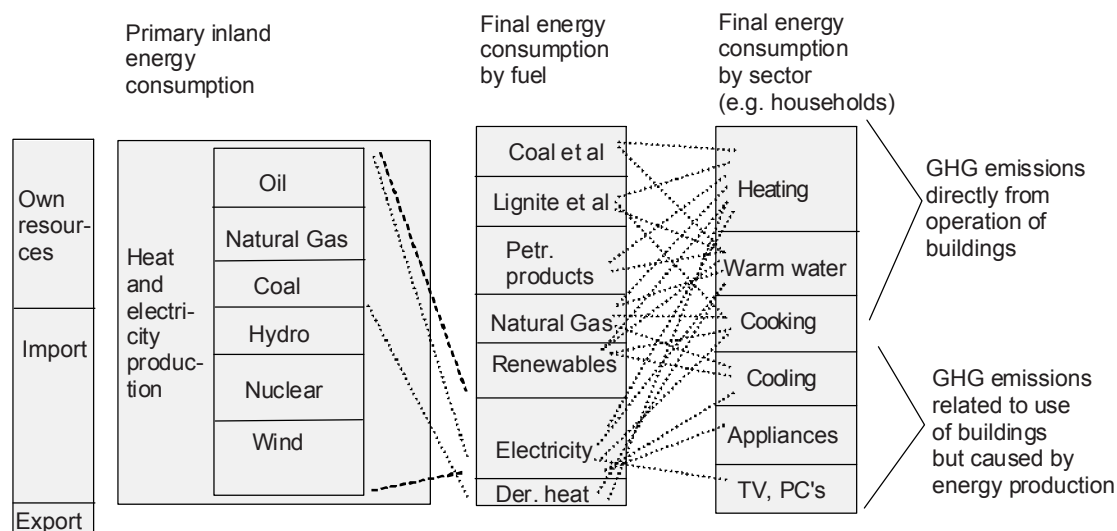


Figure 6.1.2. Context to identify energy-related problems and opportunities.

In European statistics – based on official statistics of the Member States – energy-related information is based on measured data on production and consumption. GHG or CO₂ emissions can be calculated based on source of energy. Macro-economic data is however only indicative with respect to potential of technical improvements in the building stock. Several studies have been conducted in order to combine the relevant technical information about buildings with the energy consumption data.

Reduction of energy consumption in buildings and its environmental and economic impacts can be studied through various scenarios and by the aid of various frameworks (Figure 6.1.3).

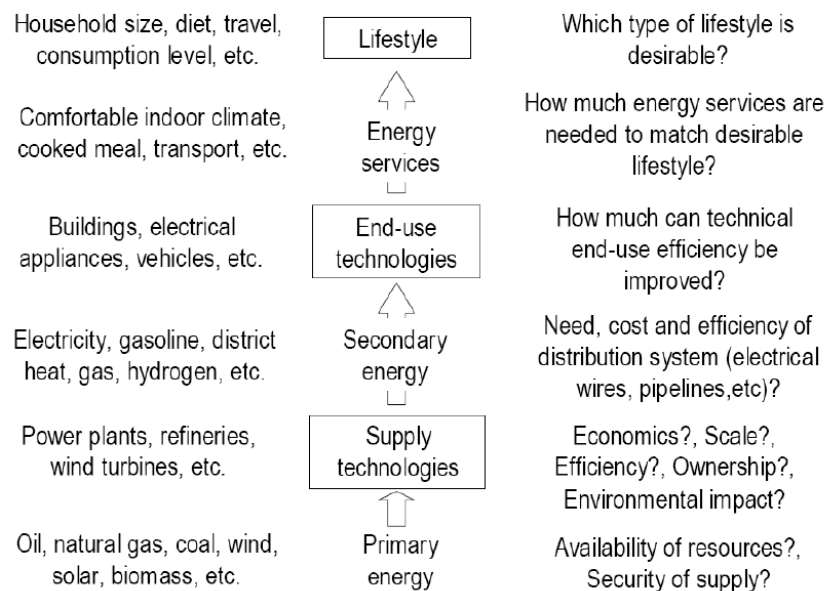


Figure 6.1.3. System analysis – covering the whole energy chain (DTU 2008).

The CO₂ emissions of residential buildings in the EU27 were 10% of total energy-related emissions and those of service sector 6% in 2005 (EEA 2008). In these figures, energy and heat production is excluded; its share was 27%. The tons of CO₂ equivalent per a ton of oil equivalent of energy vary according to the energy sources; for more information see e.g. the Report 8 of the EEA (2006).

The greenhouse gas emissions from energy consumption in buildings have been decreasing at a longer run in Europe (Table 6.1.4). This is partly due to improved efficiency of the building stock, but also that of appliances and equipment.

Table 6.1.4. Greenhouse gas emissions from energy use in buildings (services and households) in EU27, except electricity; proportion of all the GHG emissions (EEA 2009)

Statistical sector	Share of total GHG	Share of total GHG	Change in years	
			1990-2007	2000-2007
Services	3.5	3.1	- 17.8	- 5.0
Households	8.7	7.7	- 17.3	- 11.6

Reducing growth in electricity consumption will be crucial from an environmental viewpoint, especially for consumption from fossil-fuel based electricity. Two to three units of energy input are needed for producing one unit of electricity from fossil fuels with the rest being lost in the process, unless the heat is recovered in combined heat and power process.

6.1.2.4 Embodied energy of a building

Embodied energy is the energy consumed by all processes associated with the production of a building, from the acquisition of natural resources to delivery, and to the maintenance and repair activities during the operational phase. Example of embodied energy in low-energy case-study buildings in Sweden, Norway and Denmark is shown in Figure 6.1.4. Research has shown that the embodied energy content of a building can be the equivalent of many years of operational energy. Basic information can be found in literature and databases (Table 6.1.5).

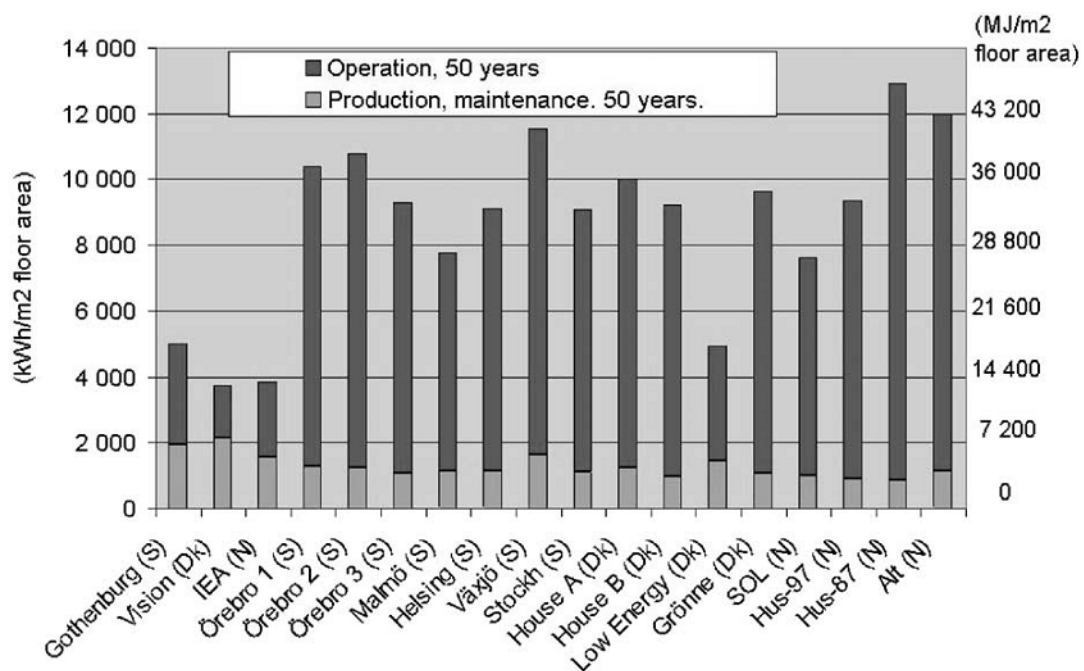


Figure 6.1.4. Example of the breakdown of embodied and operational energy in a building (Thormark 2002)

Table 6.1.5. Example of embodied energy of a composite steel beam and concrete slab (steeluniversity 2007).

Years	Energy, GJ m ⁻²								CO ₂ Emissions, kg m ⁻²							
	0	10	20	30	40	50	60	0	10	20	30	40	50	60	0	60
Structure	2.6	2.7	2.7	2.8	2.8	2.8	2.9	242	246	250	254	258	262	267		
Embodied																

The importance of embodied energy calculations is increasing for two reasons: saving natural material resources increases gradually the recycling and reuse content in buildings, and reducing the total energy consumption in operation of buildings changes the share of embodied energy.

6.1.3 ENERGY PERFORMANCE OF BUILDINGS

6.1.3.1 Thermal performance characteristics

Knowledge on the energy-performance of buildings is needed for evaluation of the potential of energy-savings of existing buildings and for verification of the thermal performance of a new building during design process. The main interest is nowadays in the overall consumption in the context of indoor climate; in other words “energy conversation and thermal comfort”. This approach means that performance and interaction of all systems of a building have to be dealt at the same time (Figure 6.1.5).

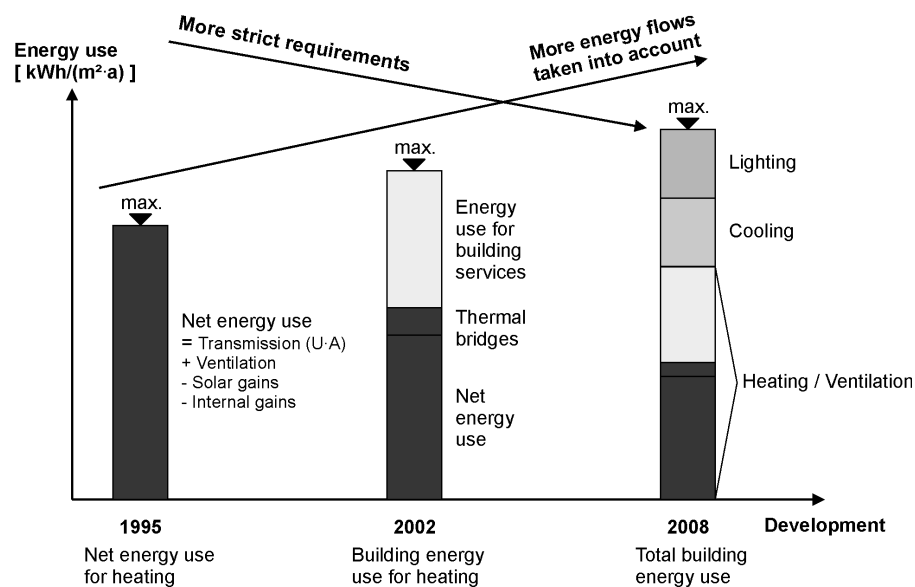


Figure 6.1.5. Development of calculation methods and requirements in Germany since 1995 for a typical single family house in Germany (Koukkari et al 2003).

As long as the construction technologies were based on natural ventilation, air leakages and varying indoor conditions, development of thermal performance was concentrating solely to envelopes. For that reason, tested values of thermal and moisture properties of materials and structural solutions, or calculations based on them, became gradually regulated. In academia, the building physics was applied to thermal performance calculations already in the beginning of 19th century.

Prescribed coefficients for heat transfer, so-called U-values (unit W/m²K) for the building's envelopes – floor, walls and roof – are used in many countries as the principal criteria for design. Nowadays, there are calculators available in the web. Also, “typical” U-values can be found there. In some countries, a more holistic ‘Energy Performance’ (EP) regulation was used (the calculated energy consumption of the building, usually expressed in kWh/m²).

The year of building construction provides useful insight with regard to the type of envelope construction. On the other hand, the history of U-values is also usable when potential of energy-savings is estimated. U-values as such do not tell about the energy-consumption unless the climatic conditions and the consumption patterns are not taken into account. This holds especially the Southern countries in which only recently the heating and cooling demands have increased. Further, the regulated U-values can in many ways differ from the actual values of buildings, to both directions.

More than half of the existing residential buildings in EU-25 were built before 1970 and about 1/3 of the dwellings were built during the 1970–1990. On an average, new European dwellings are about 60% more energy efficient than the ones constructed before the first oil crisis in the 1970s, and consume 28% less than dwellings built in 1985. Actually, the most significant improvement was observed after 1990 due to the stricter measures taken by several EU member states and the introduction of higher energy standards in the mid-1990s. As a result, dwellings built in 2002 consume 24% less than dwellings built in 1990.

The Directive on Energy Performance of Buildings EPBD (EU 2002) has adopted an integrated approach that is similar to the Construction Products Directive, CPD. In the reasoning of the EPBD, the estimation of the saving potential of 22 % by the year 2010 is based upon savings in all consumption areas, namely heating, hot water, air-conditioning and lighting. The Directive concerns the residential sector and the tertiary sector (offices, public buildings, etc.).

The key points of the Directive concerning structures are:

- Common methodology for calculating the integrated energy performance of buildings
- Minimum standards on the energy performance of new buildings and existing buildings that are subject to major renovation
- Systems for the energy certification of new and existing buildings and, for public buildings.

The status of the implementation of the EPBD to the national regulation in the Member States is presented at the EU's official webpage buildingsplatform.eu, where country reports summarize the development and give links to the national regulations and tools. Several projects have been conducted based on the new databases that utilize information collected for the certificates, e.g. under the CIP Framework Programme's Intelligent Energy Europe Programme.

A proposal for the revision of EPBD was presented by the European Commission in November 2008. This proposal of the EPBD recast recommended that all EU Member States endorse national plans and targets in order to promote the uptake of very low and close to zero energy buildings. It became endorsed in June 2010 (EU 2010). The new legislation underlines the importance of creating an energy efficient building stock as a pivotal part in the creation of a sustainable urban environment.

The aim of the EPBD recast is to clarify, strengthen and extend the scope of the 2002 directive, as well as to reduce the large differences between Member States' practices in the building sector. Overall, its provisions cover energy needs for space and hot water heating, cooling, ventilation and lighting for new and existing, residential and non-residential buildings. Net zero energy buildings are now the goal within the action plan for new buildings.

6.1.3.2 *Modeling and simulation*

Modelling and simulation based on building physics and thermodynamics are sophisticated methods for analysis of components, structures, buildings or even building stocks. They are extensively used in calculating heat losses and temperatures in buildings, in order to verify thermal performance during a design process. There are hundreds of software tools and guidelines on the market.

Data for an energy simulation is basically the same as that for simplified energy calculation. Before carrying out the simulation, one must collect information about the local climatic data, building design, air-conditioning system and control method. The local outdoor climatic conditions over a year are an important piece of information and it is better to have the hourly values of the climatic data. This data is often recorded in a typical year. If the weather data for a particular location is not available, it may take a lot of efforts to collect and establish this data.

The dynamic simulation of building energy consumption focuses on the hourly variations of the outdoor climatic conditions and the indoor design criteria about temperature and humidity. The air-conditioning loads and energy consumption for 8760 hours in a year or for several years are determined. Beside the part-load energy consumption, the maximum load over the year(s) will also be included.

The modelling methods are used also to analyse the condition of a building stock in an area, suburb, city or a country, and further to assess the needs and solutions of technical improve-

ments (Figure 6.1.6). In a model, typical buildings are rated for specific annual energy consumption per m^2 , and then the surface of each age-class is multiplied by the specific annual energy consumption to predict the overall consumption (Kohler & Hasler 2002). Other factors and indicators can be chosen for modeling, especially when trends and impacts are studied like in Erabuild report about renovation market. Validation of these models can be achieved by comparing the sum of estimated consumption to the statistically known building energy consumption.

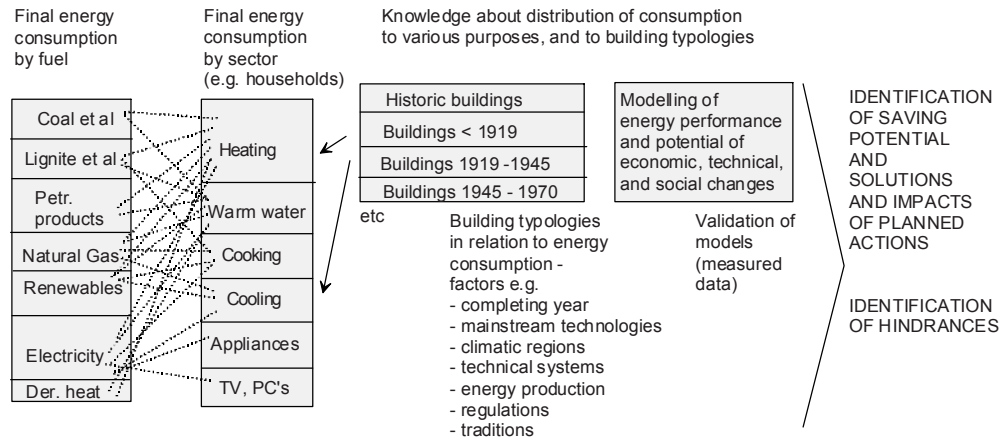


Figure 6.1.6. Identification of potential of energy-efficient of building stock by modeling.

6.1.4 STRATEGIES TO IMPROVE SUSTAINABLE CONSTRUCTION

6.1.4.1 District level solutions

Research and development as well as demonstration and dissemination programmes of the European Unions various organisations are emphasizing district and community level policies and solutions for energy-related challenges. Europe has launched various programmes such as ECO-BUILDINGS (more than 100 projects from FP 5, FP 6 and FP 7 in many different European cities), CONCERTO (18 projects covering 46 different CONCERTO communities), SAVE projects in Intelligent Energy Europe (in total about 50 projects), ERACOBUILD, as well as a number of related national programmes.

In European Action Plans aiming at improved environmental performance of products and services, integrated approaches are favoured. In energy-efficiency – and overall sustainability – urban planning approaches play an important role.

Integrated research and development is requested also in the implementation of the European Economy recovery Plan through the Framework Programme 7: “Research on the application of technological, design and organisational improvements at district-level with the aim of reducing the energy and resource consumption” is expected.

6.1.4.2 Passive and zero-energy building concepts

The energy-efficiency goals of buildings have been studied in the context of the whole building stock and built environment. There are arguments that only the zero-energy or energy neutral solutions of new buildings will have the desired impact to the needs of absolute savings; less stringent goals of new building means savings of 50-80% in space heating compared the average level of current use. Various concepts have been developed in many countries. For example, NREL participates in the United States in “creation of the technology and knowledge base for cost-effective zero-energy buildings by 2025. A zero energy building is defined in the following way (NERL 2007): “...produces as much energy on-site as it consumes on an annual basis, primarily through energy efficiency with any small remaining loads met by photovoltaics and other solar energy technologies”. The Energy Research Centre of the Netherlands gives a

definition of a zero-energy house that “annually the energy demand can be met by locally generated renewable energy” (Opstelten et al. 2007).

In fact, low energy buildings are known under different names across Europe. A survey carried out in 2008 by the Concerted Action supporting EPBD identified 17 different terms in use to describe such buildings used across Europe, among which the terms low energy house, high-performance house, passive house/Passivhaus, zero carbon house, zero energy house, energy savings house, energy positive house, 3-litre house etc (Commission 2008). In the relevant literature additional terms such as ultra-low energy house can be found. Finally, concepts that take into account more parameters than energy demand again use special terms such as eco-building or green building. Variations exist not only as regards the terms chosen, but also what energy use is included in the definition. Ideally, the minimum performance requirements should take into account all types of energy use that is demand for space heating (cooling), water heating, air conditioning as well as consumption of electricity. This is often not the case. On the contrary, the definition may cover only space heating ignoring all electricity demand that may cover most heating needs for instance in office buildings. The following illustration on selected low energy performance standards shows the different scopes and calculation methods:

A Passive House concept has been under development since the 90ies. The Passive House Institute has given a definition that it is “a building in which the heat requirement is so low that a separate heating system is not necessary and there is no loss of comfort” (Feist 1997). The concept is gaining more and more support among practitioners and stake-holders, as it introduces clear targets for energy-consumption in technical terms. In total, more than 6.000 houses have now been built in Germany and elsewhere in central Europe (for example Austria, Belgium, Switzerland, Sweden) which conform to the Passivhaus standard. The standard fundamentally consists of three elements: i) an energy limit; ii) a quality requirement; iii) a defined set of preferred Passive Systems with cost efficiency.

The Passive House has a heating demand of 15 kWh/m² floor area per year, whilst the total primary energy use in the house is restricted to 120 kWh/m² per year (see Figure 6.1.7).

For the Northern Scandinavia and other countries with cold climates, a more flexible definition of the Passive House concept is set. For Southern climates (<40° latitude), where passive cooling is more dominant, a second addition to the definition should be made:

- Nordic passive houses (> 60° northern latitudes)
- Central European passive Houses (40° - 60° northern latitude)
- Mediterranean passive houses (IEE project Passive-On < 40° northern latitude)

According the most optimistic but still realistic scenario of the potential savings, the passive houses are projected to realize a goal that exceeds the Kyoto target in the new building sector.

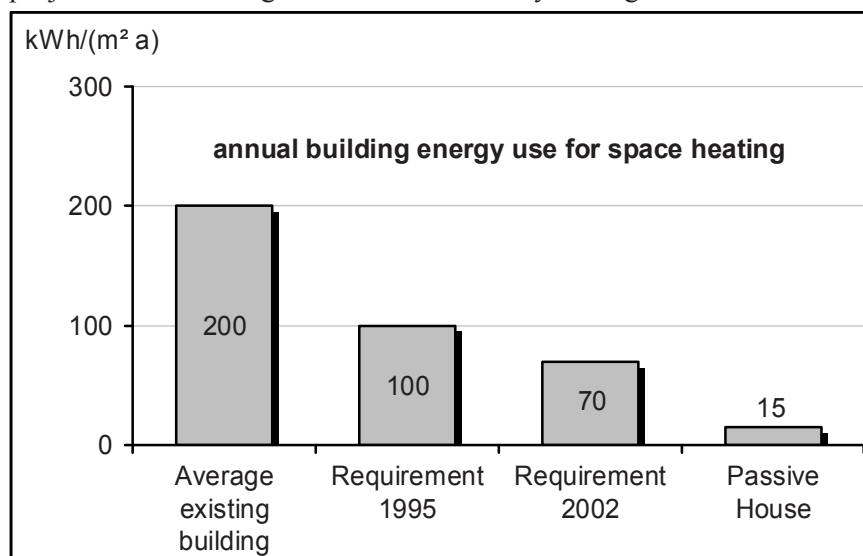


Figure 6.1.7. Annual building energy use for space heating (net energy use for heating) for single family houses in Germany (Koukkari et al 2007)

6.1.4.3 Uptake of new technologies for energy-efficiency

According to the survey of the IPCC (2007), there is a broad array of accessible and cost-effective technologies and know-how to reduce energy losses during the operation of buildings. Several other projects and political communication are in agreement with this view; for example ENPER– Project (2007) concludes: “With respect to the 2020 horizon, there is a need for innovative concepts in terms of a large-scale market implementation of well-proven technologies (thermal insulation, efficient boilers, heat pumps, energy-efficient ventilation, efficient lighting, use of renewables, etc). No new major technological innovation is required.”

However, at the longer run there are needs of technological innovations. The novel solutions are searched from rapid developments of material sciences and technologies as well as miniaturizing of monitoring technologies.

Microprocessors can be used to control solar thermal and photovoltaic systems, heat storage, sun-shading, ventilation and back-up heat, and provide electrical power management. Energy management use computer-based monitoring systems to optimize the performance and interaction of systems, and more often the various systems are interacting as an intelligent building. They integrate monitoring and control of heating and cooling systems, lighting, building envelope shading, elevators, security, fire control systems and many other subsystems.

Recent research has shown that the savings potential of advanced control systems alone is of the order of 190 PJ of primary energy per year in the whole Dutch built environment, and 12 Mtoe CO₂ emission reduction (Opstelten et al. 2007). The control systems are classified as environment-adaptive, user-adaptive and user-educational (interactive), and the latter one is an evolving area. It requires simultaneous simulation and extending the current software tools.

Table 6.1.6. Examples of the advanced and alternative technologies for buildings

Potential	Targeted technical effects
Modified natural solutions	<ul style="list-style-type: none"> - increased/empowered ventilation - cooling with cold water - passive solar shades - green roofs and facades
Advanced materials	<ul style="list-style-type: none"> - energy storing, dissipation, - smart materials, phase changing materials, thermoelectric materials - high-reflectivity, cooling (new hybrids) - use of solar energy (space heating, water heating) - high-efficiency lighting - insulation materials

Table 6.1.6. Examples of the advanced and alternative technologies for buildings – cont.

Potential	Targeted technical effects
Advanced facades and roofs	<ul style="list-style-type: none"> - reduction of heating or cooling needs - light-weight and free forms - reduction of thicknesses (e.g. vacuum solutions, Hastings 2004) - minimizing or selecting the infiltration of outside air - building integrated photovoltaics (to produce electricity and also act as a building material)
Advanced windows	<ul style="list-style-type: none"> - reduction of heating/cooling needs (multiple, superior, selective or vacuum glazing) - control the amount of solar heat that passes through the window glass (electrochromic or "smart" windows) - motorized blind or shades
Integrated design	<ul style="list-style-type: none"> - effective use of ambient energy sources and heat sinks - effective control strategies (integrated design of windows and HVAC systems)
Integrated products	<ul style="list-style-type: none"> - use of massive structures (floors, facades) - technical services integrated in the core structures - multifunctionality (electricity, heat, aesthetic, structure)
Intelligent building technologies	<ul style="list-style-type: none"> - dynamic and adaptive overall management of systems - educational control systems
Industrialized production	<ul style="list-style-type: none"> - air-tight and easy-to-assemble connections

There are several disciplines and industrial branches that are interested and involved in the research and development work aiming at new solutions for the construction sector. The objectives and roadmaps developed among the various European Technology platforms give good introductions to the advanced and alternative technologies. Similar concepts can be found in several European projects (Table 6.1.6).

6.1.4.4 *Strategic alliances and public-private-partnerships*

Considering the huge politic efforts and investment of the European Union towards a more energy-efficient building sector as well as the industrial awareness of the urgency of the situation it is expected a fast implementation of the EU energy policy.

A good example of this strong will is the document “Multiannual Roadmap and Longer Term Strategy”, presented in December 2009 by the Ad-hoc Industrial Advisory Group of the Energy Efficient Building European Initiative (E2B EI), Energy Efficient Buildings Association (E2BA) and the European Construction Technology Platform (ECTP), and published by the European commission in 2010 (EU 2010^b).

The EeB PPP Roadmap defines research priorities and “wave” actions for industry assuming that the knowledge gained in the first “waves” feeds into the successive of projects at the design stage, realising the continuous implementation of the process.

As a result of this “wave action” it is expected to achieve an impact following a stepped approach within a ten year time perspective, namely:

- Step 1: Reducing the energy use of buildings and its negative impacts on environment;
- Step 2: Buildings cover their own energy needs;
- Step 3: Transformation of buildings into energy providers, preferably at district level.

The EeB PPP Roadmap also identified several overlaps across the three application areas (Existing Buildings, New Buildings and Districts/Communities) of the research priorities and respective actions. Figure 6.1.8 shows the inter-relationship among the research challenges, high-lighting those “cross-cutting challenges” which are relevant for more than one of the application areas. For instance, this is the case of “Energy Storage”, which is identified as “cross-cutting challenge” as well as a specific challenge for Districts/Communities, or “Systems and Equipment for Energy Use”, which is identified as a “cross-cutting challenge” as well as a specific challenge for New and Existing Buildings.

Although, it is clear that some of the cross-cutting challenges build on different requirements and address different constraints, depending on the application area considered, the type of research required, including expertise and knowledge, is quite similar.

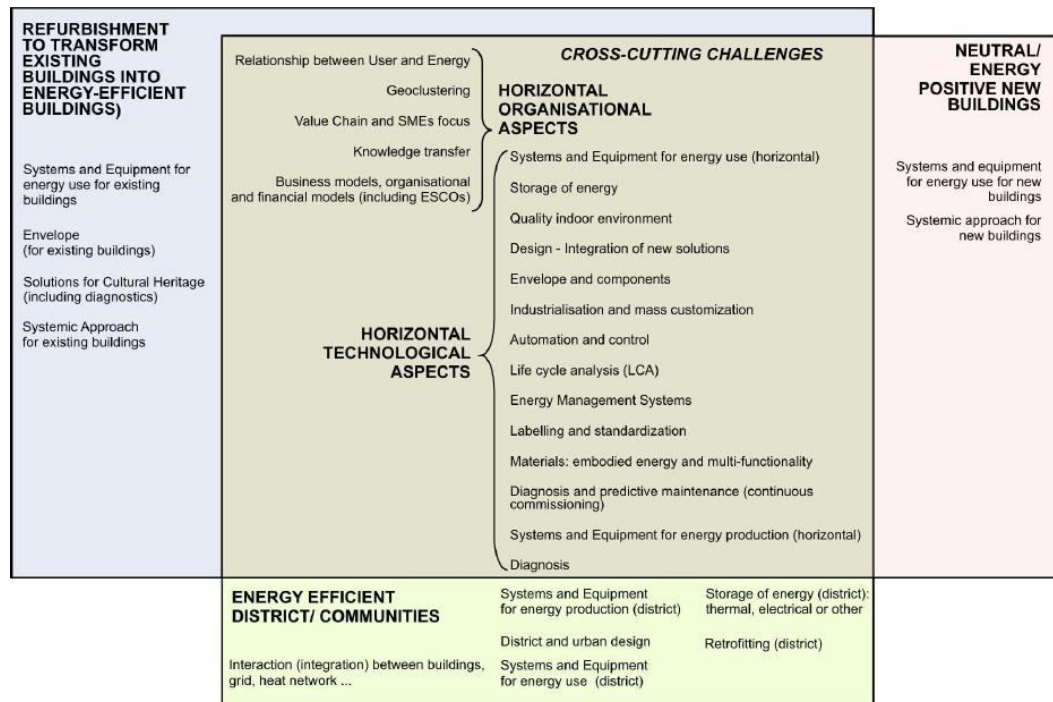


Figure 6.1.8. Inter-relationship among research challenges (EeB PPP Roadmap).

6.1.5 CONCLUSIONS

Energy-efficiency of the European economy is a major political challenge that calls for changes in all sectors of production and consumption. About 40% of energy is consumed in operation and use of residential and service sector buildings, and a lion's share of that consumption goes for managing indoor climate (temperature, humidity, indoor emissions).

The greenhouse gas emissions counted for "buildings" are caused by energy produced and consumed inside one building or a block of buildings, but also by energy that is produced at distance, e.g. district heating and electricity. As a consequence, the purpose of energy use and the way this particular energy is produced needs to be known in order to find roadmaps and solutions for energy saving. This leads to the needs to model the energy performance in various types of building classes (typologies). The macro-economic statistical information is a good basis for this kind of approach but it needs to be completed with actual and relevant data. Several European projects have been performed aiming at reliable information about the true market potential that is based on analysis of the building stock. New data is gathered nowadays also from the energy certificates that are prepared based on implementation of the Energy Efficient Buildings Directive.

Research in Europe is done at several levels and from various points of views. District level studies aim at integrated solutions of energy production and consumption; on the other hand, behaviour of individual consumers is studied in relation to use of technical systems and selection of equipment. Uptake of new and emerging technologies and new innovations is high in agenda which might support cost-efficient upgrading of the building stock. There are apparent differences in energy consumption patterns between various European countries. Thus, many projects are also dealing with technology transfer of best practices, and methods to take the new technologies in use.

Improving energy-efficiency of buildings is a part of promotion of sustainable construction. The other aspects of sustainability are also important for harmonious development of the European built environment to fit with needs of users, society, economy and environment.

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